Summary of Phase 2 Upgrade Tracking Studies

Mark Grimes on behalf of the
Tracker Upgrade Simulation Working Group

CMS Upgrade Workshop - Fermilab - 29/Oct/09

Simulation Setup

- CMSSW 2.2.6 fast simulation, but with full digitisation using full simulation code.
- Non-iterative tracking with full pattern recognition.
- Efficiency and fake rate plots made using the MultiTrackValidator (some minor changes to fix some 2.2.6 bugs).

$$\text{Efficiency} = \frac{\#\ \textit{truth particles associated to a track}}{\#\ \textit{truth particles}}$$

$$\text{Fake rate} = \frac{\#\ \textit{tracks not associated to a truth particle}}{\#\ \textit{tracks}}$$

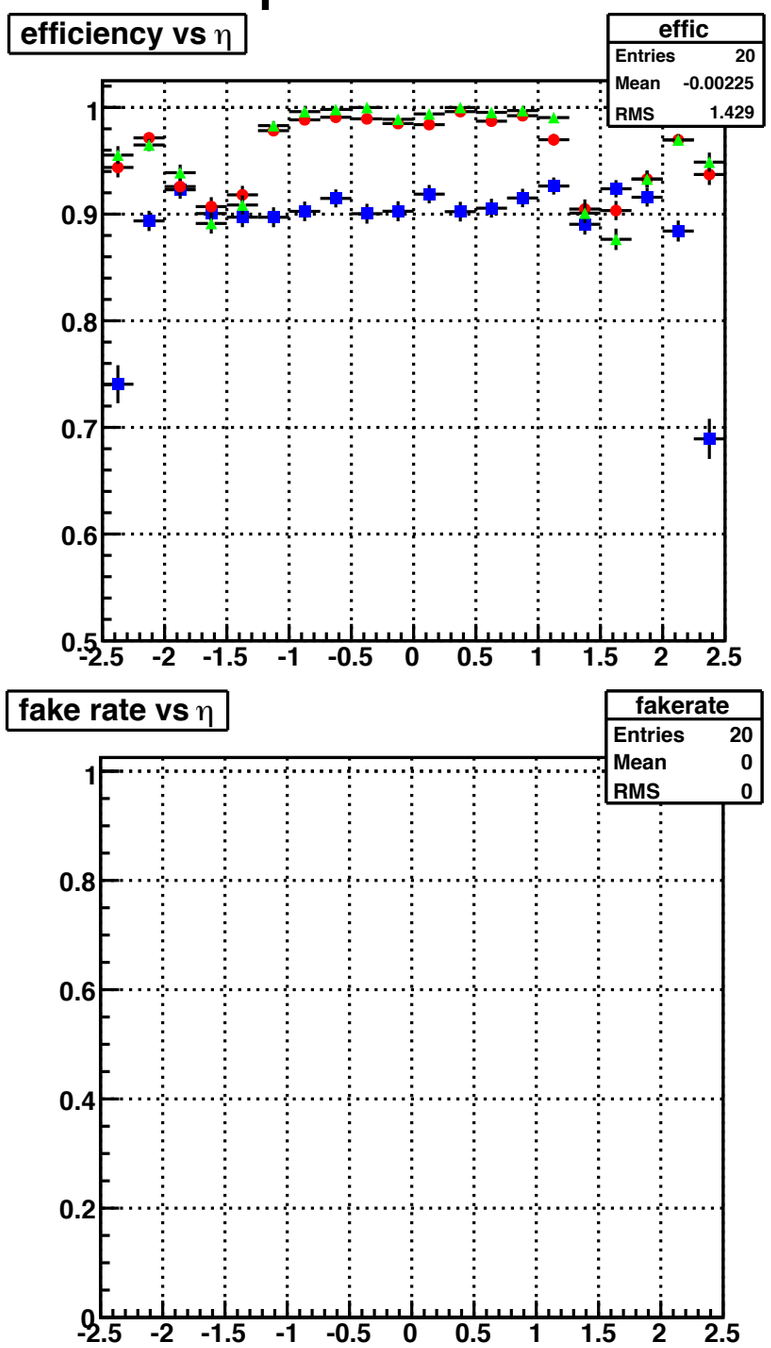
Initial Studies

Started testing the efficiencies and fake rates using di-muon and di-jet samples

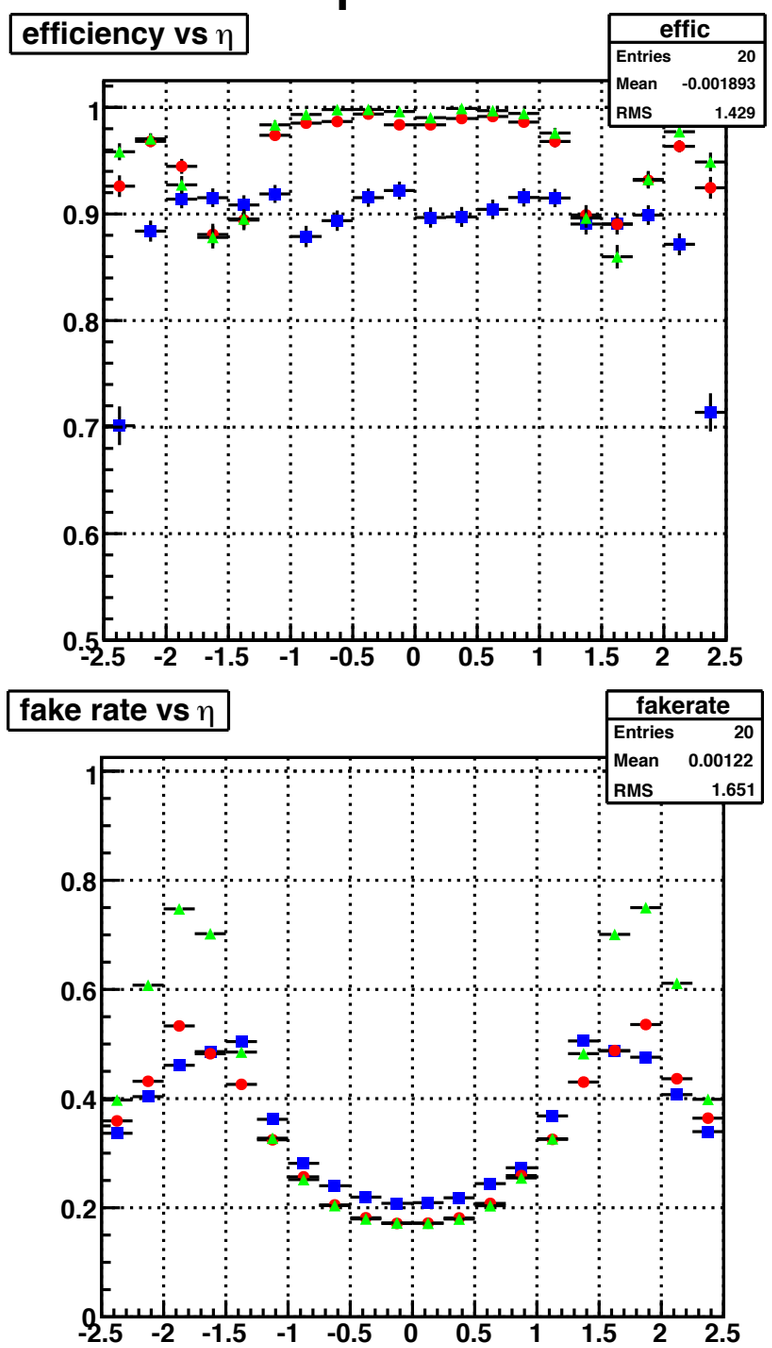
- Found huge fake rates at high pile up
  - would not be able to live with those rates, so need better track selection.
- Fake rates particularly high in the transition region.
  - not quite fully understood - under investigation.

Studies with di-muons (0.9-50 GeV p_T)

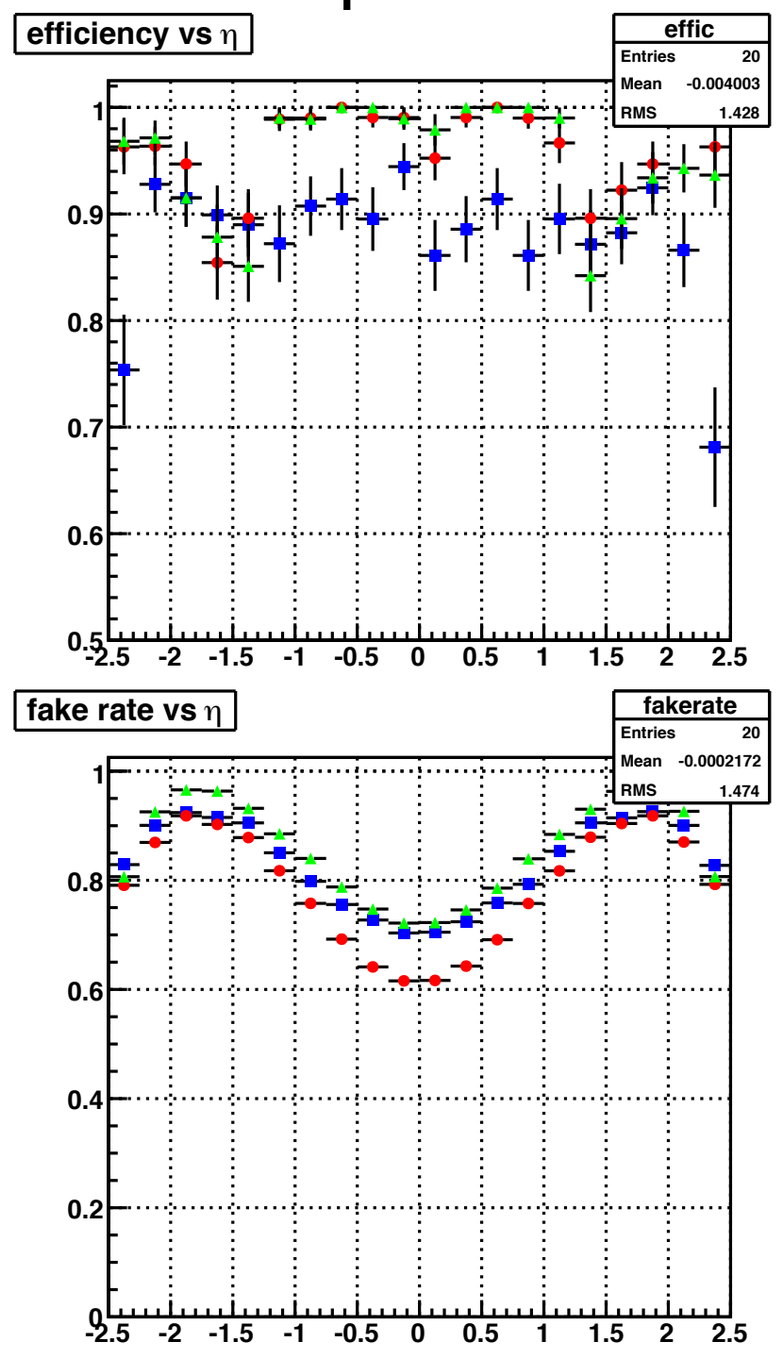
0 Pile Up



100 Pile Up



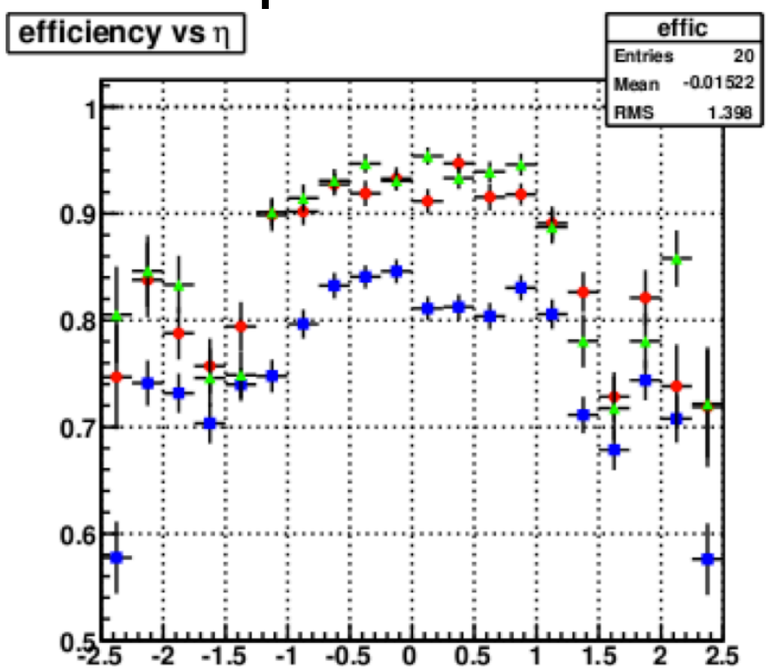
250 Pile Up

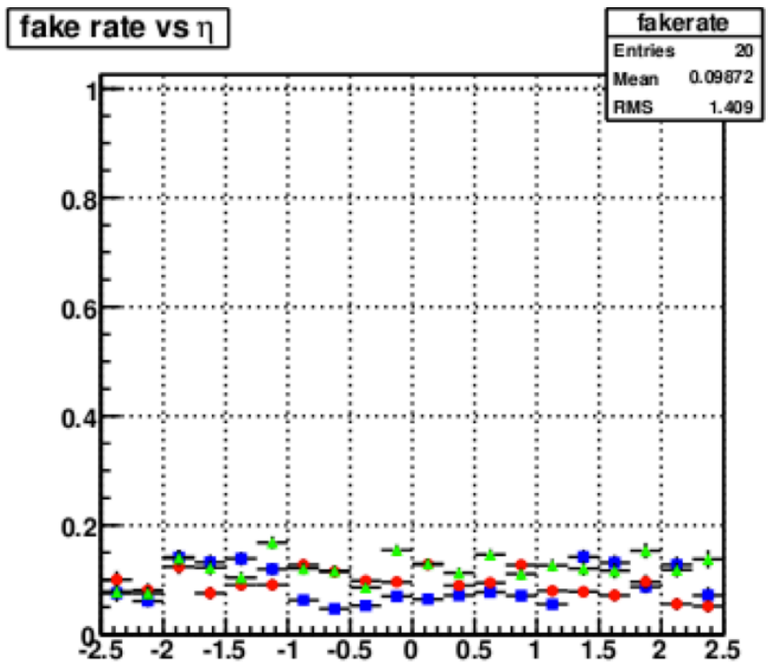


Standard Longbarrel Hybrid

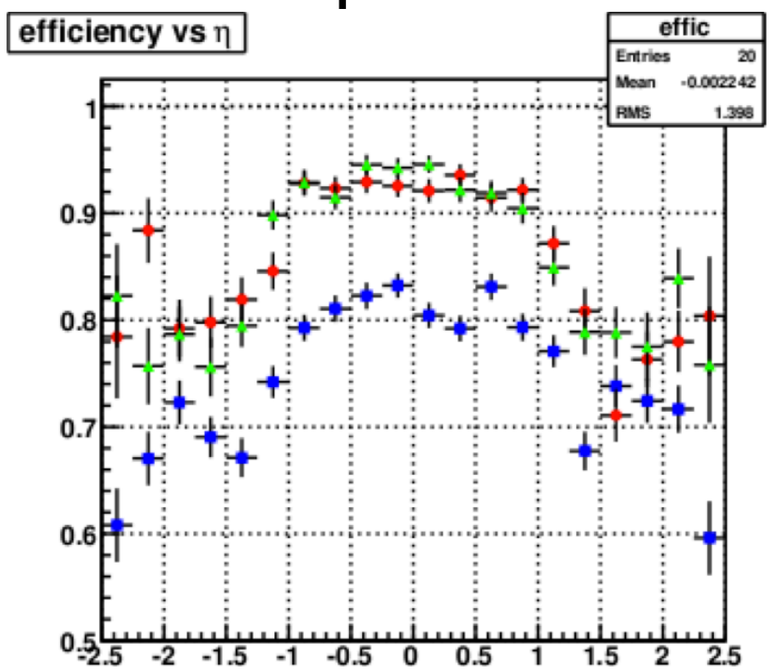
Studies with di-jets (500-520 GeV p_T, others studied)

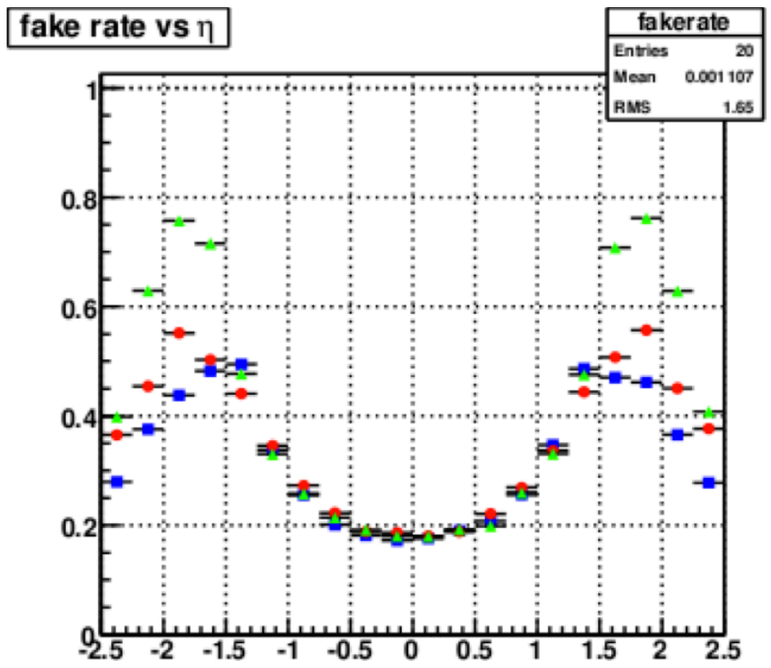
0 Pile Up



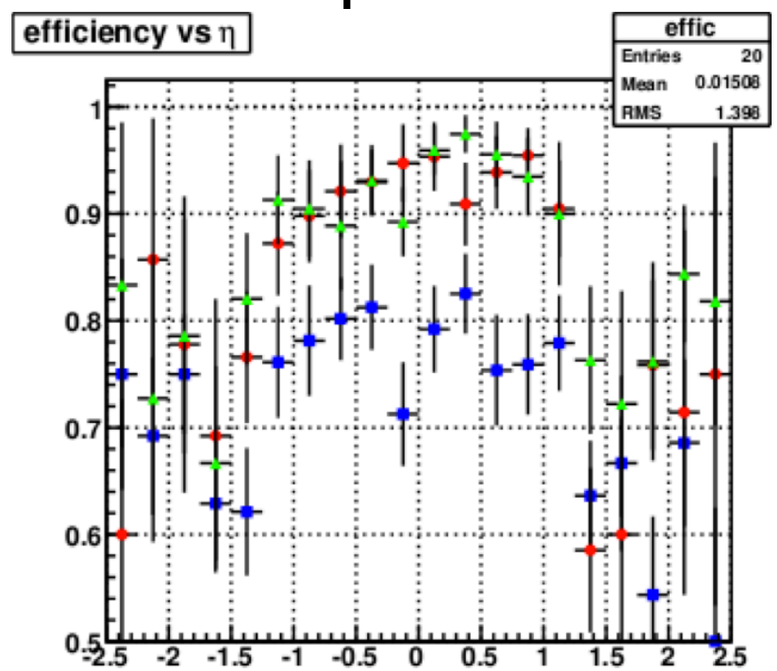


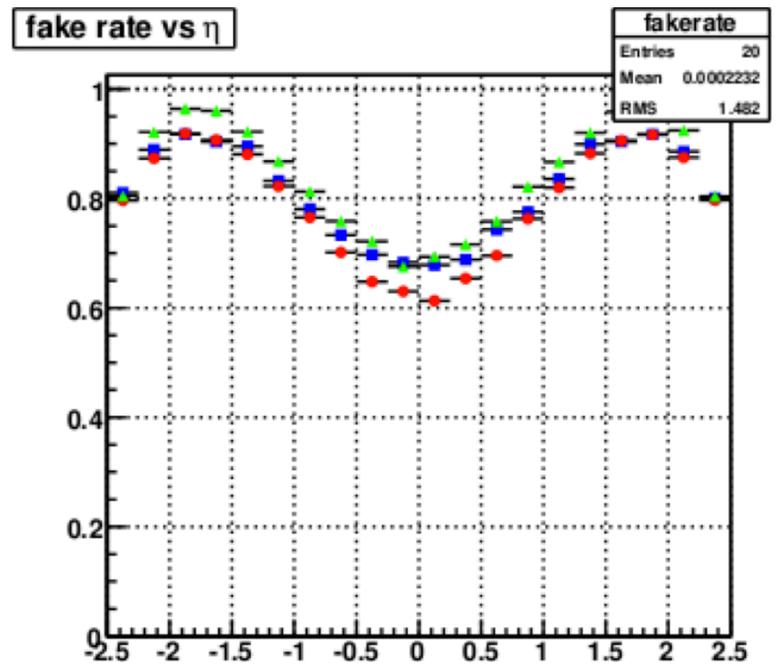
100 Pile Up





250 Pile Up





Standard Longbarrel Hybrid

Ferdinando Giordano & John Ellison

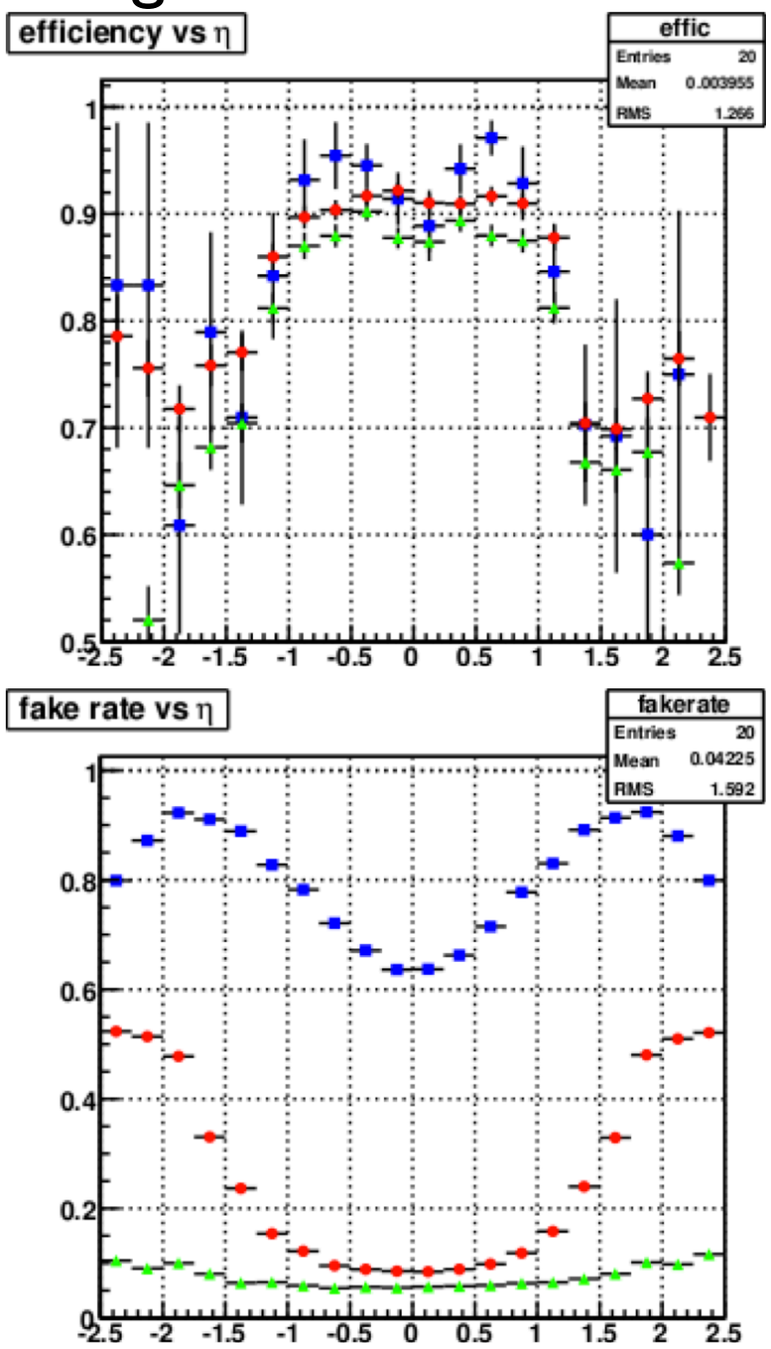
Reducing The Fake Rate

Applying a cut on the number of layers with hits reduces the fake rate.

- Requiring at least 6 layers with hits drastically reduces the fake rate with minimal affect on the efficiency.
- Requiring at least 8 layers starts to impact on the efficiency in the forward region. The tracker performance group cut on 8 layers (before switching to iterative tracking), but the upgrade geometries have fewer layers.
- Hybrid still has high fake rates in the transition region.

Reducing The Fake Rate

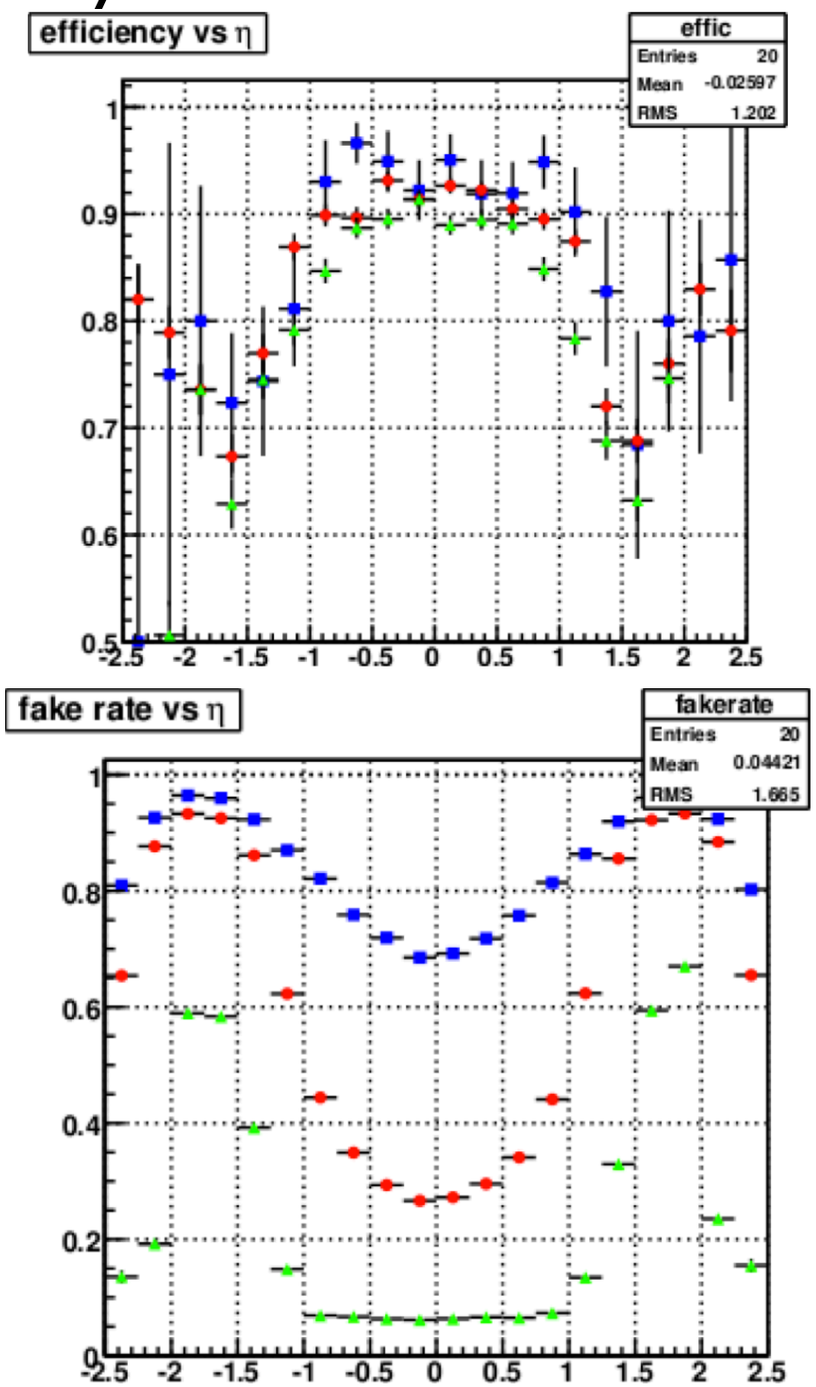
Longbarrel



1000-1020 GeV jets,
250 pile up

- 3 Hits
- 6 Hits
- 8 Hits

Hybrid



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Current Studies

- Cutting on the number of layers with hits is a little crude, need to find a better way of optimising
  - should move to iterative tracking.
- Not much difference in efficiency between the upgrade geometries
  - moved to looking at other particles:
    - electrons
    - pions

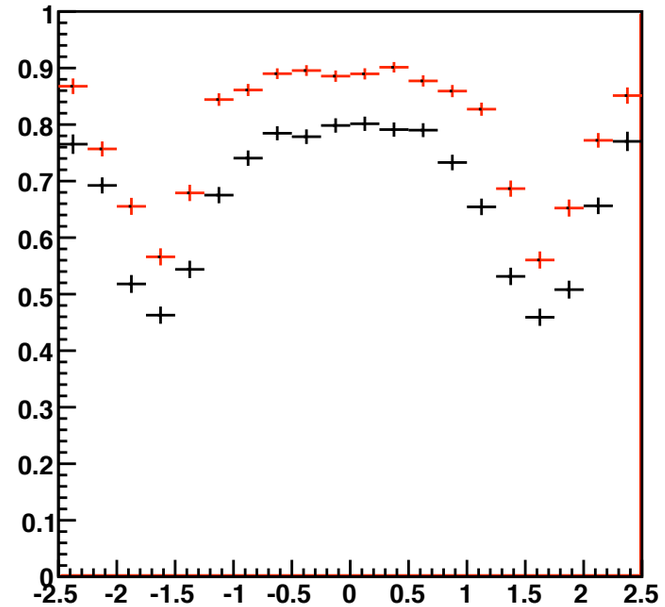
Studies with electrons

- Checked efficiency and fake rates with electrons.
- Hybrid shows similar efficiency to the tracker Detector Performance Group validation plots.
- Longbarrel shows reduced efficiency
  - still investigating

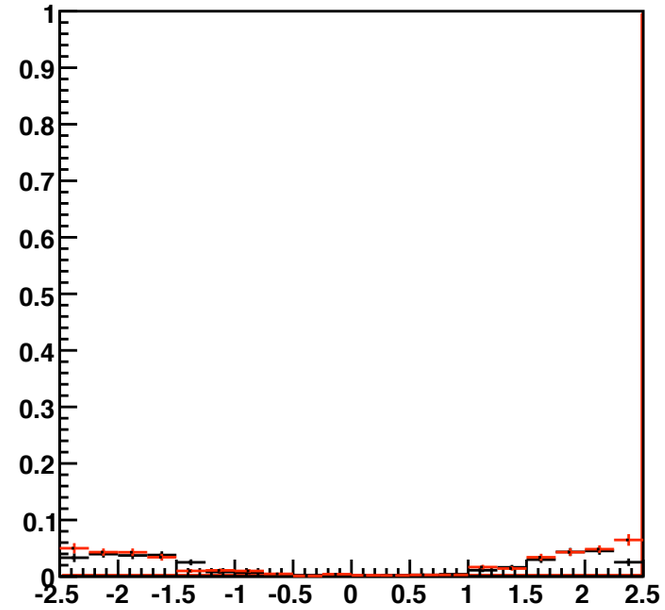
Studies with electrons

0 Pile Up

efficiency vs η

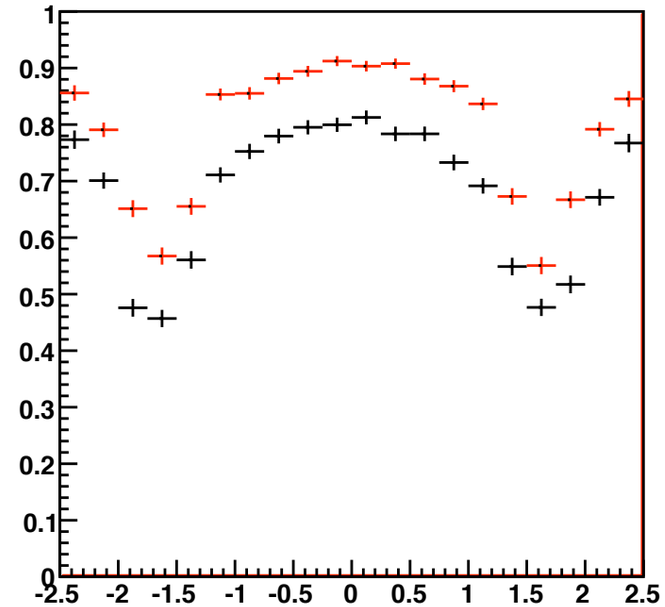


fake rate vs η

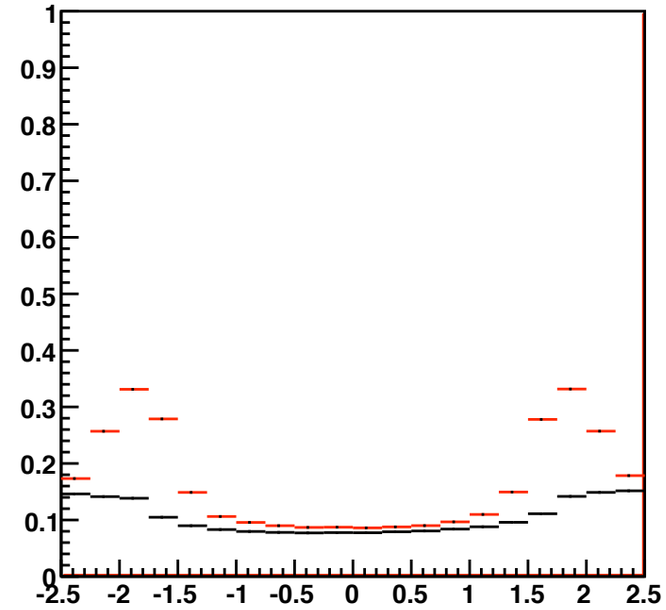


50 Pile Up

efficiency vs η

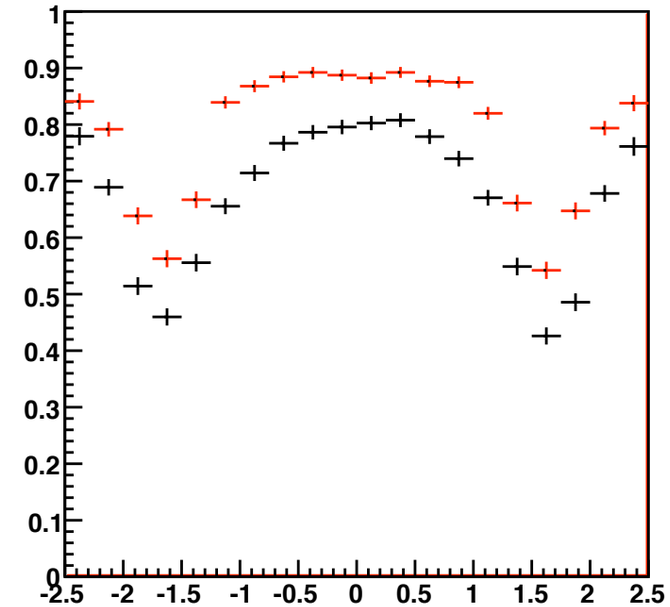


fake rate vs η

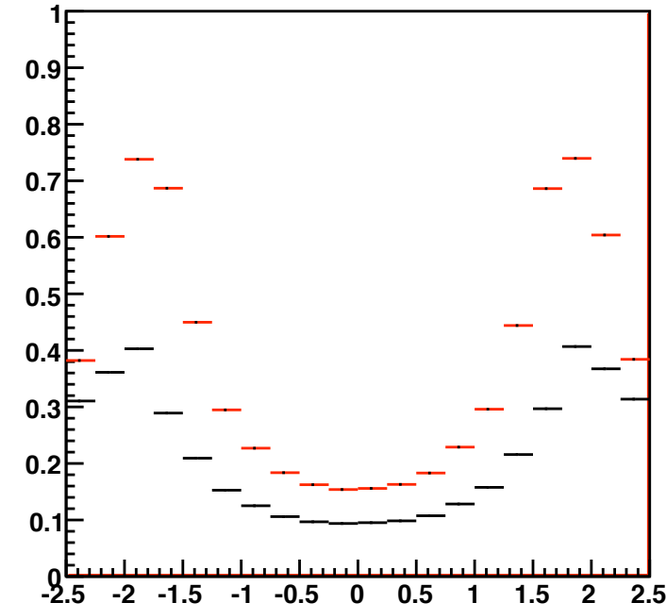


100 Pile Up

efficiency vs η



fake rate vs η

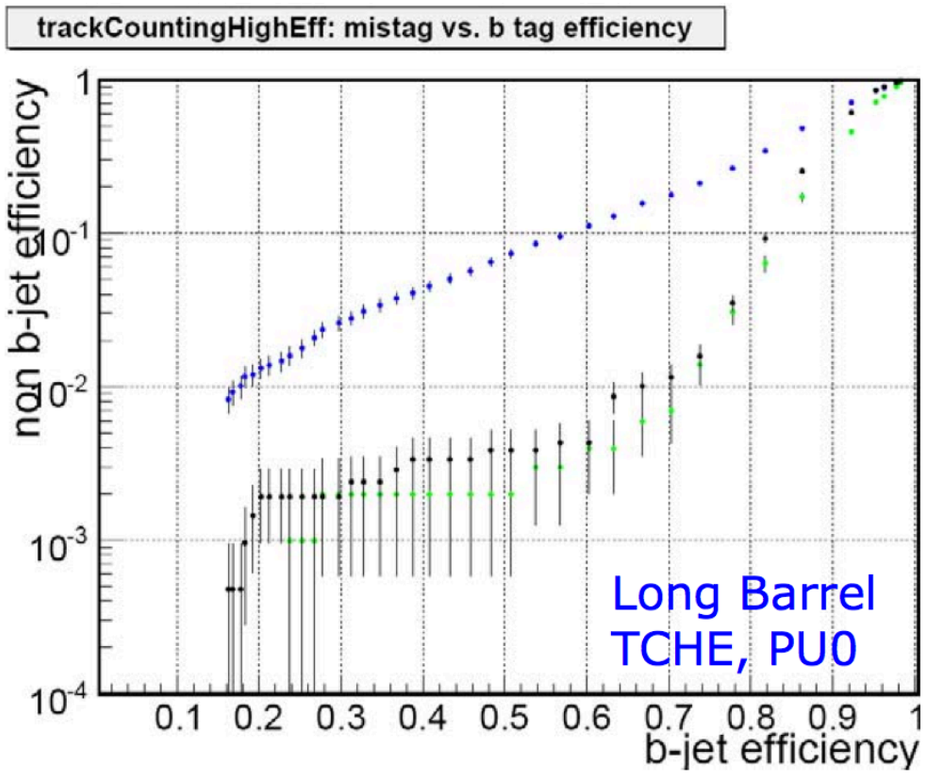


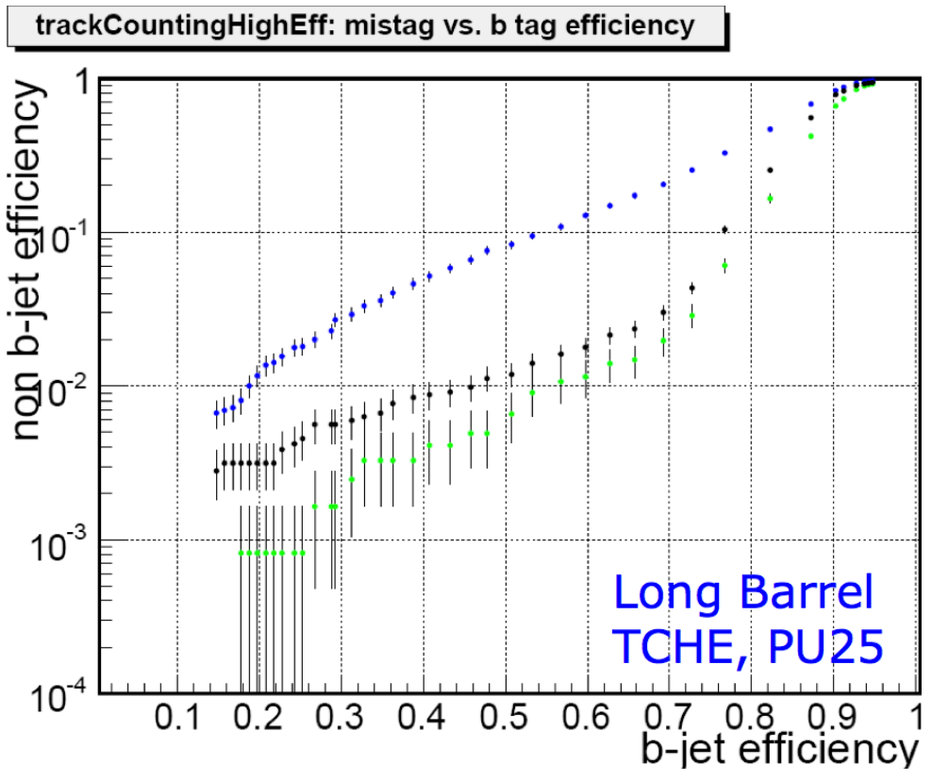
Longbarrel Hybrid

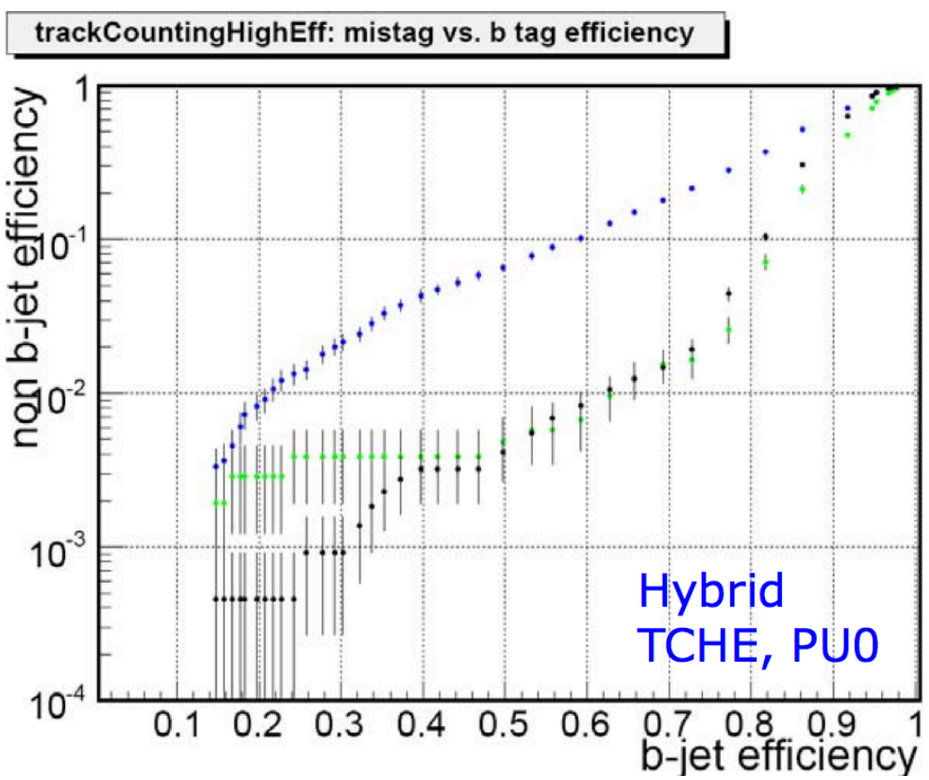
B-tagging

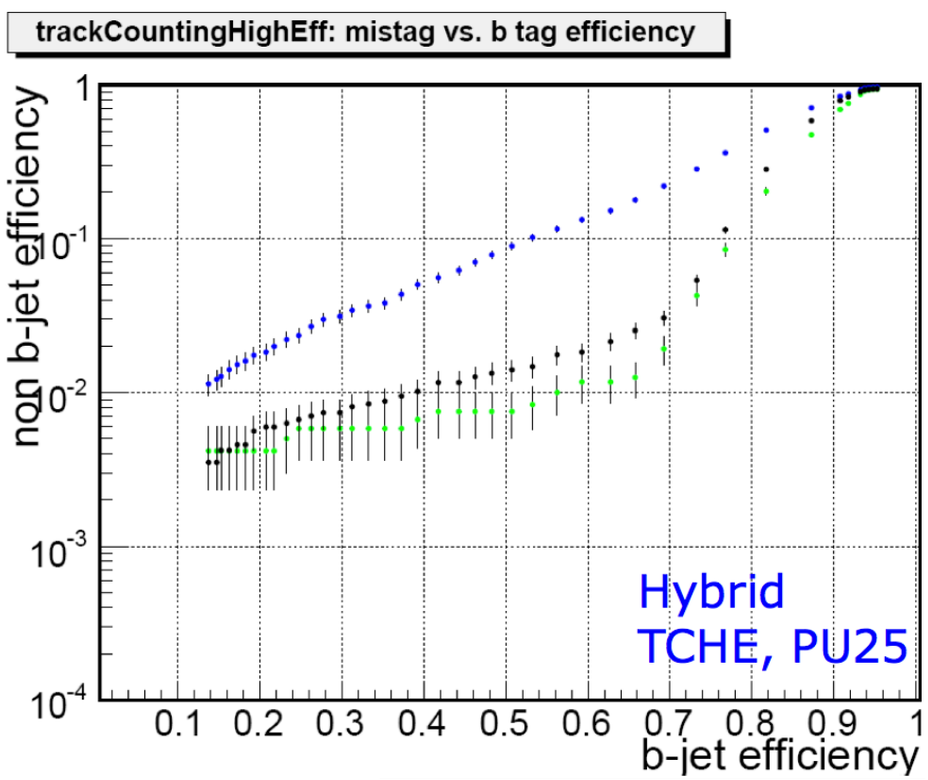
- Efforts also started on checking b-tagging
  - so far only 0 and 25 pile up
  - 50-120 GeV p_T jets
- No significant difference seen between Longbarrel and Hybrid so far.

B-tagging









gluon jets
uds jets
c jets

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Detector Variations

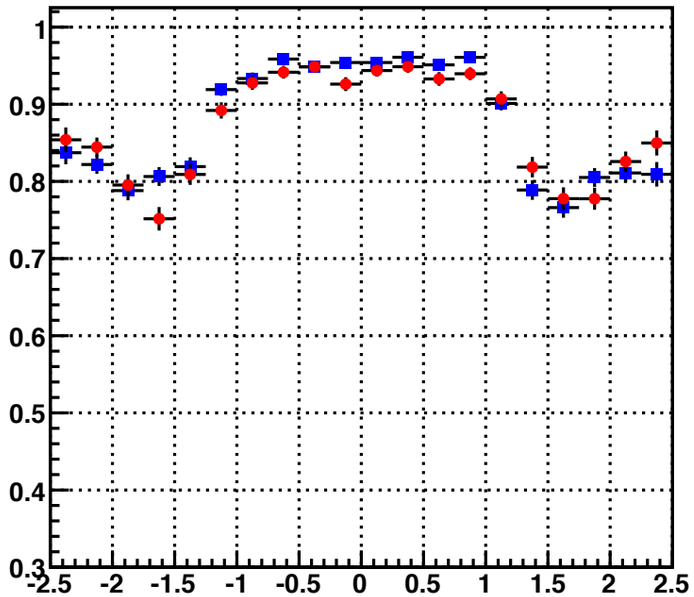
- Studied the change in efficiencies and fake rates with granularity in the Longbarrel geometry
  - moved from 100μm x 1mm pixel size to 250μm x 2mm.
- Only noticeable change is the fake rate at high pile up
  - can be easily negated by cutting on the number of hits.

Longbarrel Granularity

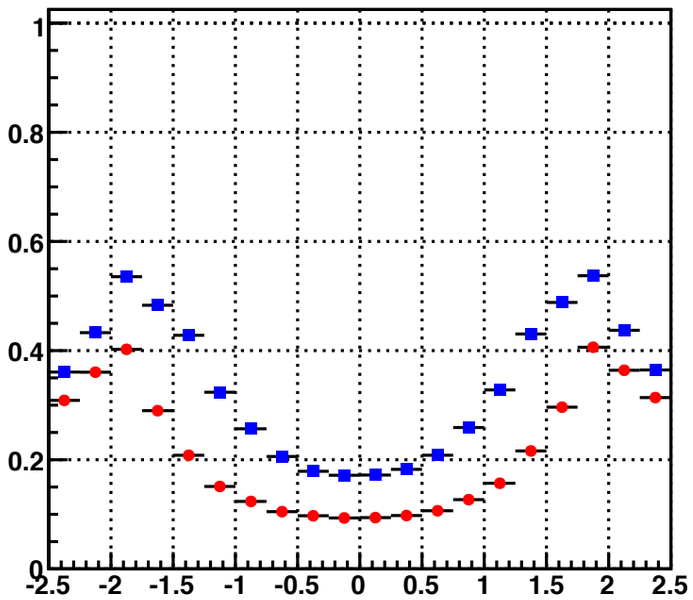
0.9-50 GeV pT
Di-pions, 100 Pile Up

3 Hits

efficiency vs η

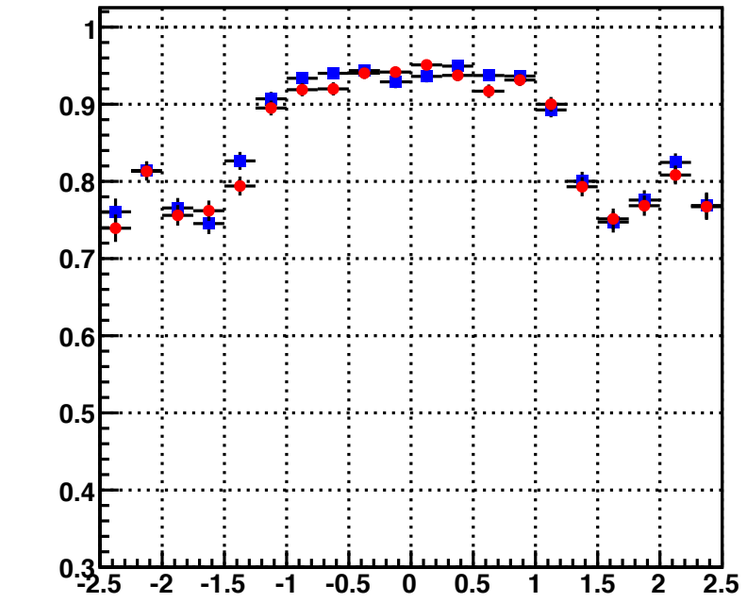


fake rate vs η

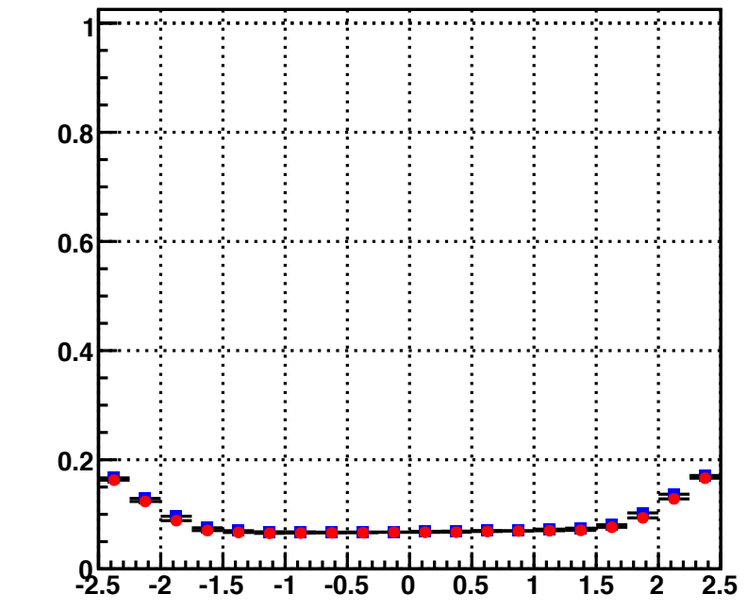


6 Hits

efficiency vs η



fake rate vs η



Low granularity (250µm x 2mm) Normal (100µm x 1mm)

Detector Variations

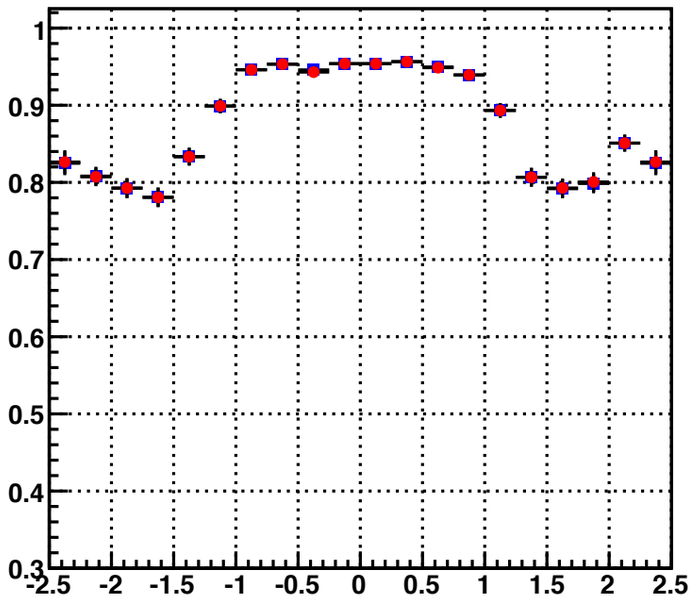
- Also looked at the readout
  - tried 1 bit ADC readout instead of 8 bit
  - low granularity in both cases
- No noticeable change.

Longbarrel Readout

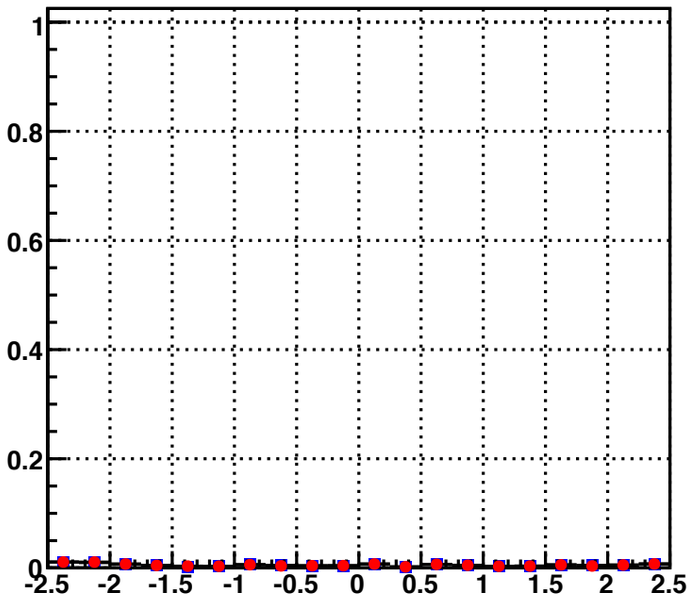
0.9-50 GeV pT
Di-pions

0 Pile Up

efficiency vs η

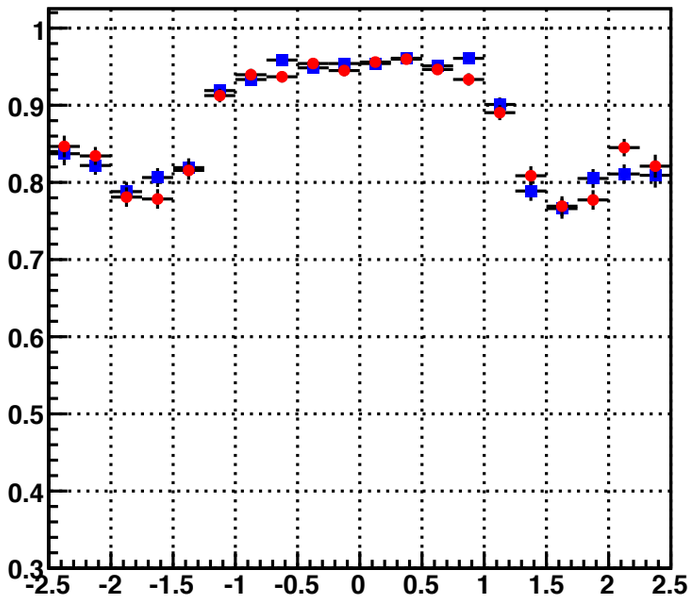


fake rate vs η

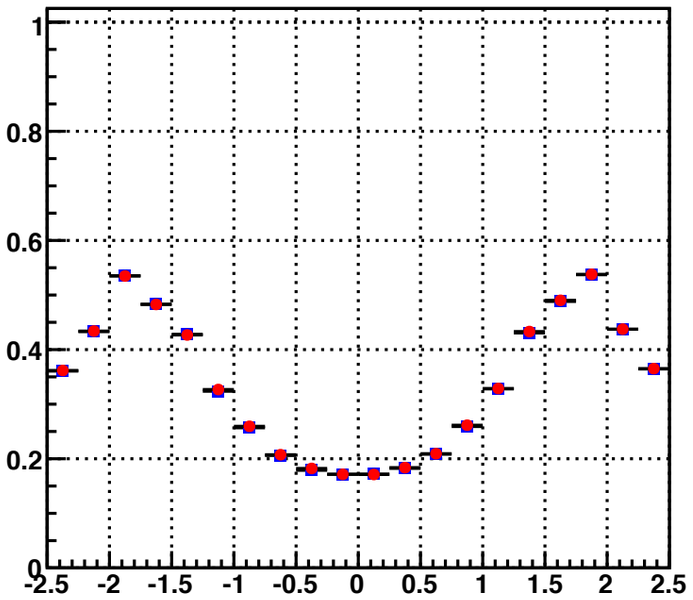


100 Pile Up

efficiency vs η

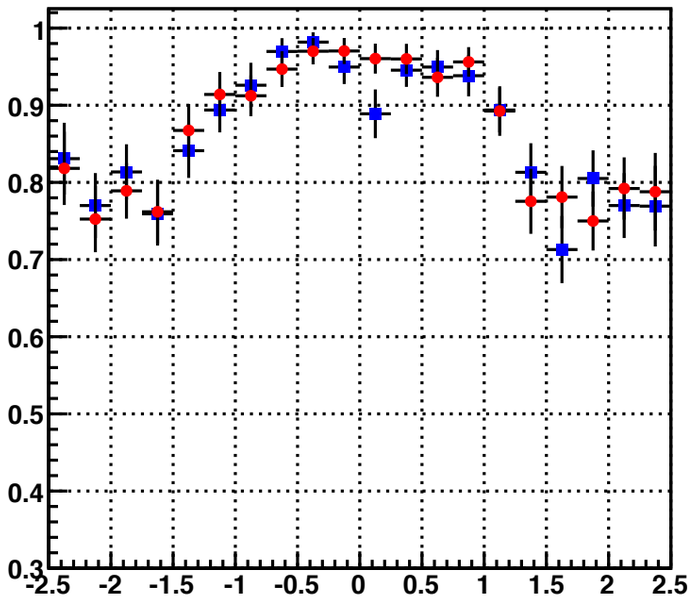


fake rate vs η

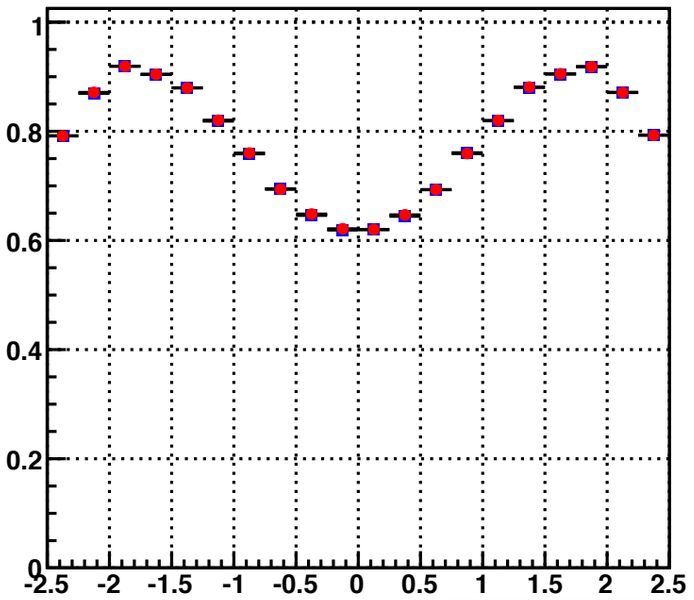


250 Pile Up

efficiency vs η



fake rate vs η



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8 bit ADC readout 1 bit ADC readout

Detector Variations

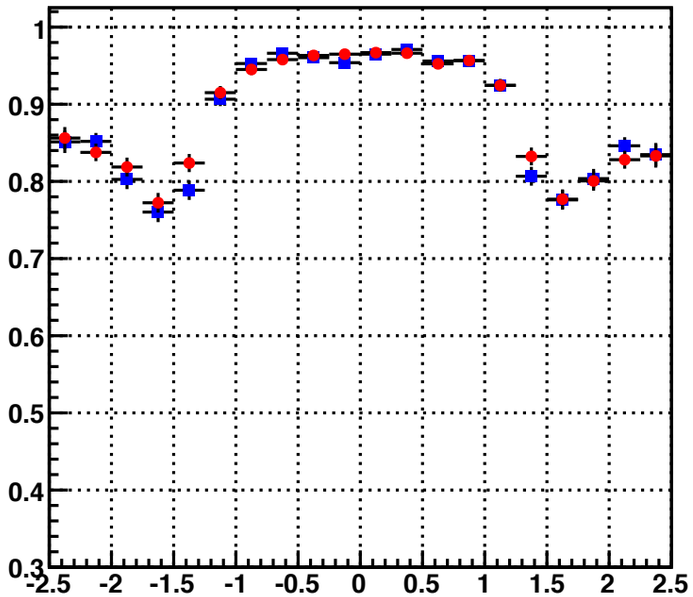
- Looked at using mono strip layers in Hybrid
  - "normal" Hybrid has the first two outer barrel layers as double sided stereo layers.
  - checked how this affects the efficiency and fake rates if these two were mono layers.
- Not much change.

Hybrid Variation

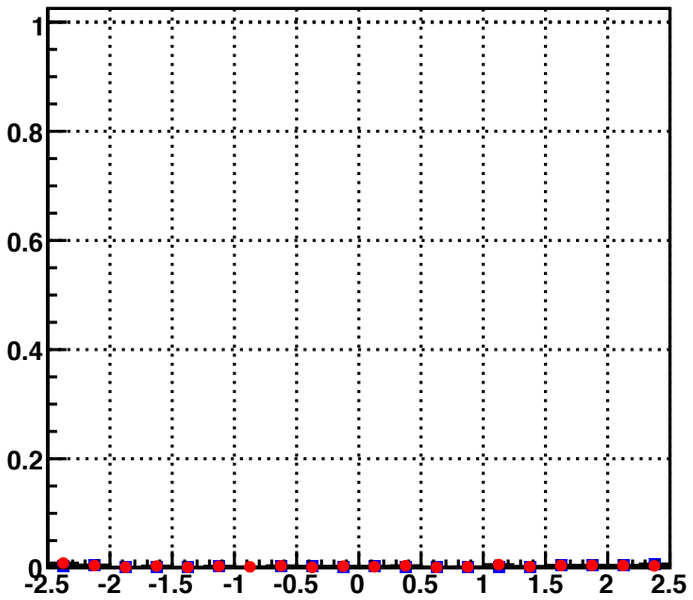
0.9-50 GeV pT
Di-pions

0 Pile Up

efficiency vs η

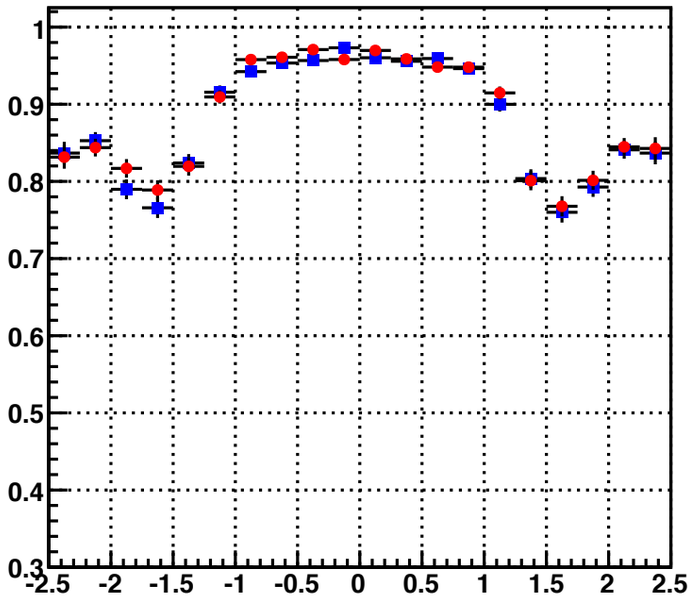


fake rate vs η

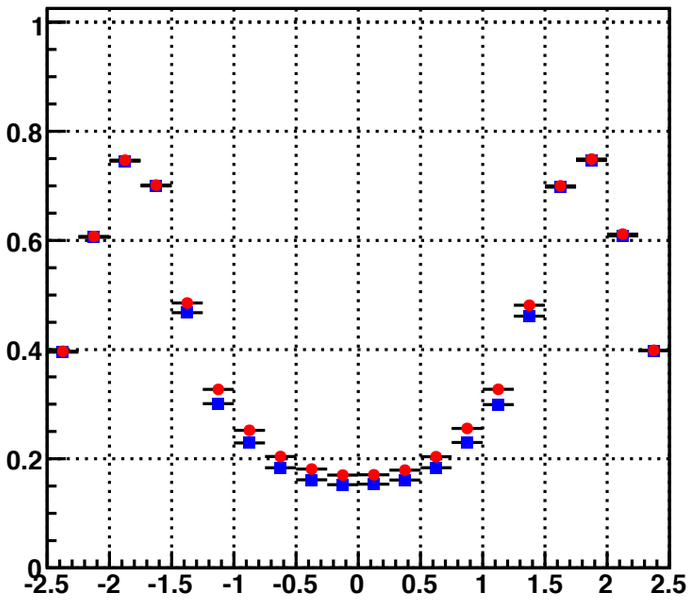


100 Pile Up

efficiency vs η

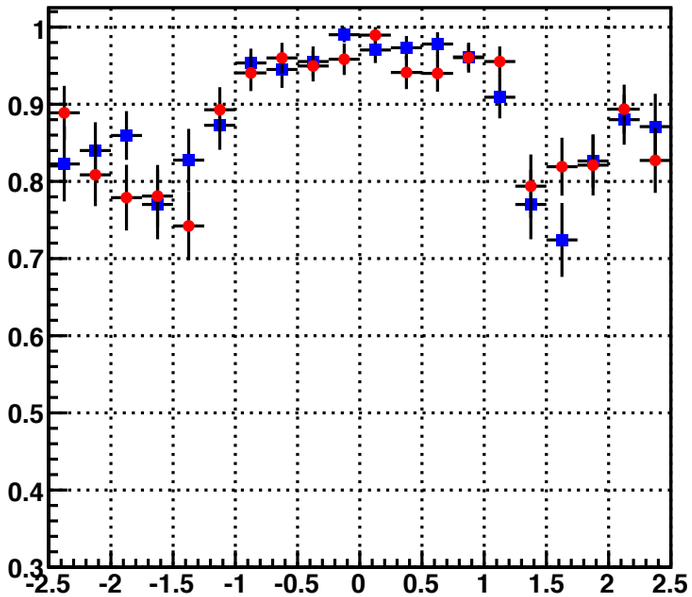


fake rate vs η

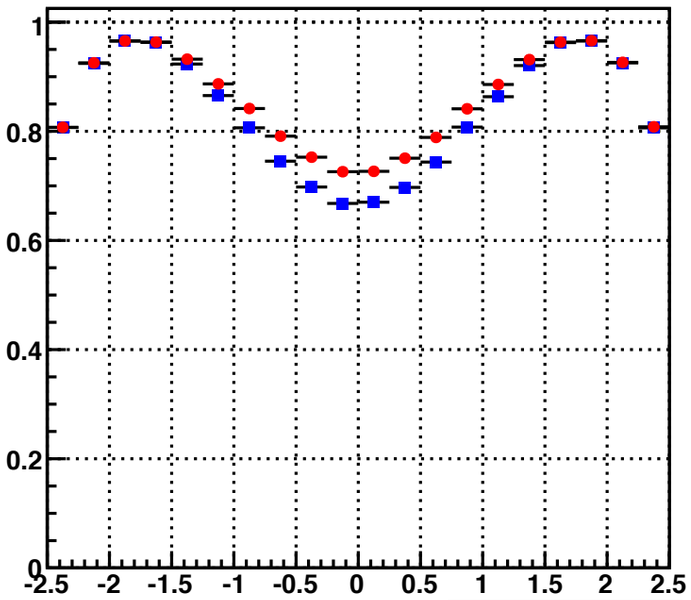


250 Pile Up

efficiency vs η



fake rate vs η



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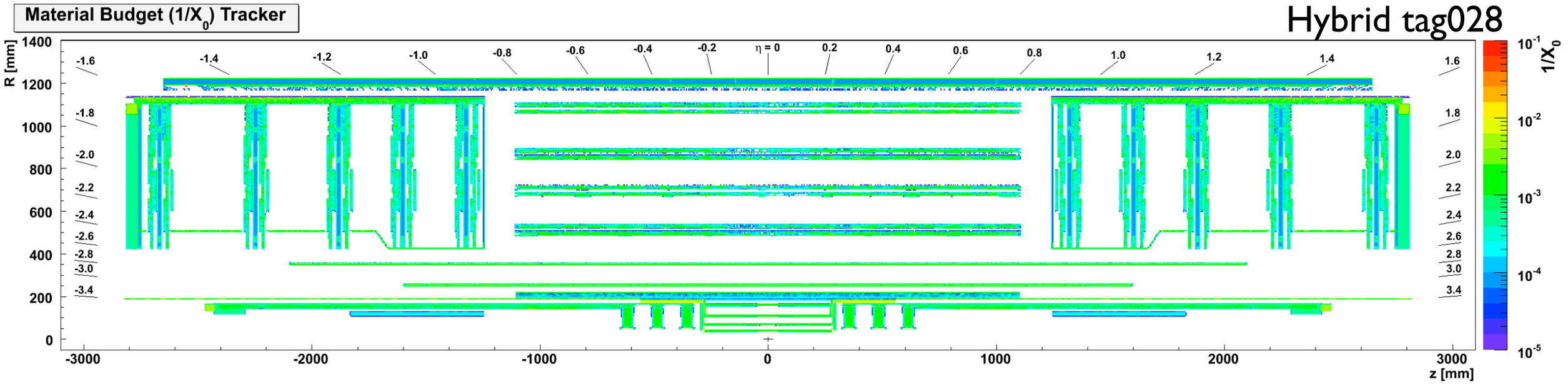
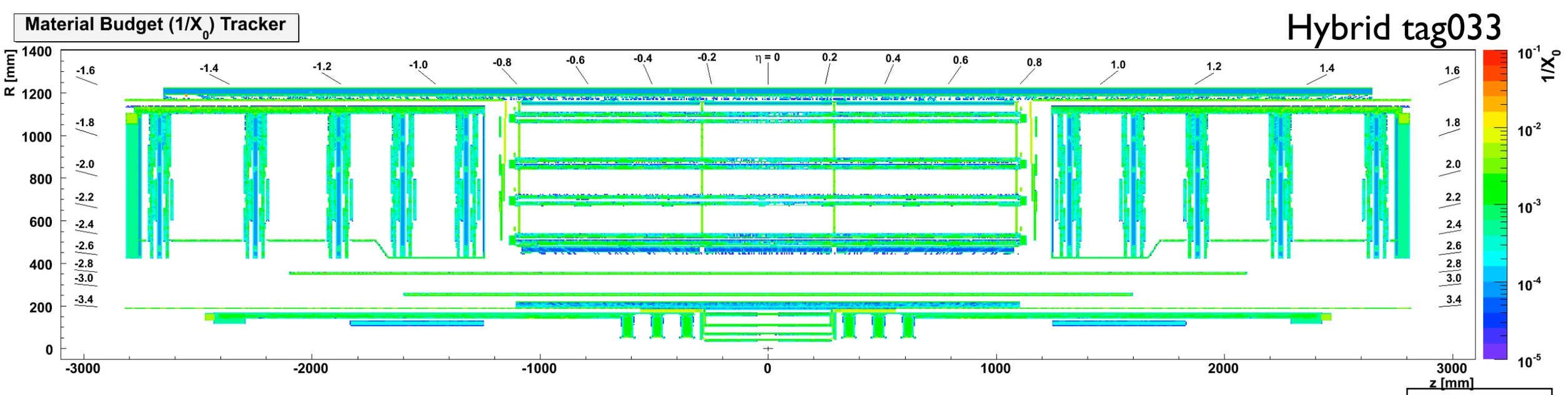
Stereo Layers Mono Layers

Future Plans - technical

- Continue improving the material descriptions
  - support material, services etcetera modelling is constantly being improved.





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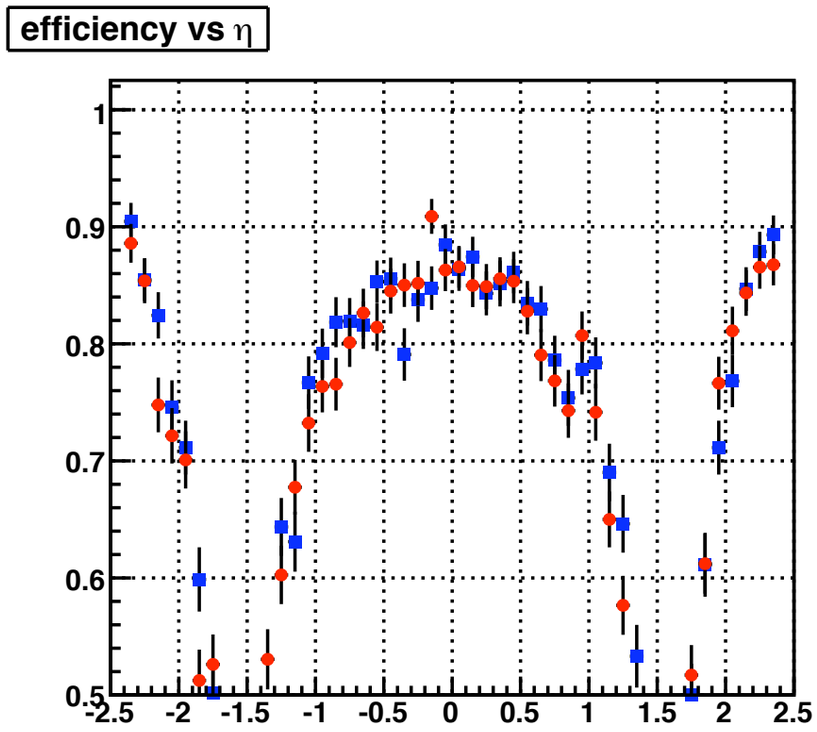
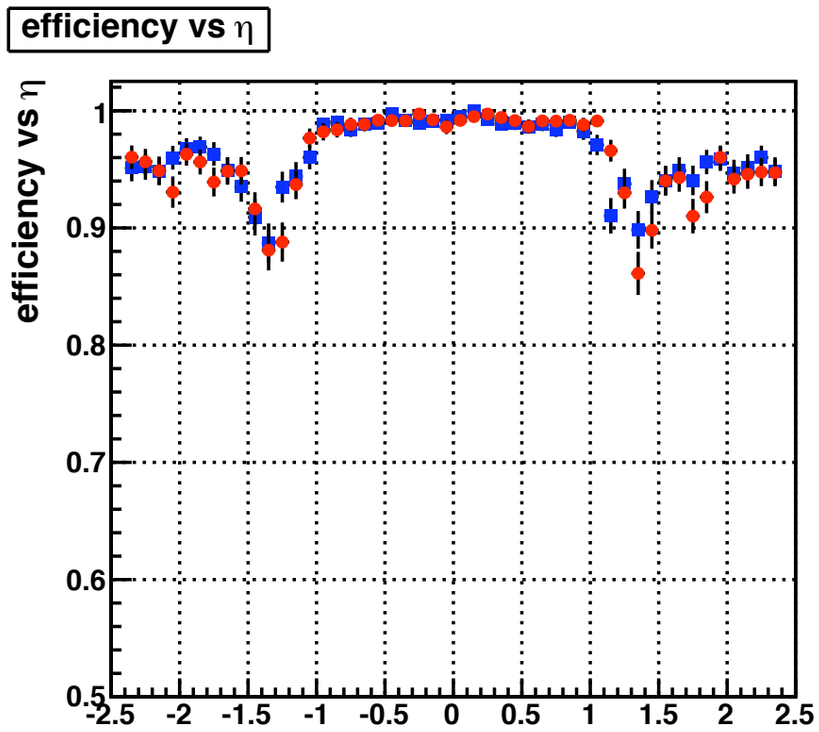
Future Plans - technical (cont.)

- Find better ways to optimise the tracking
  - iterative tracking in 3.x.x apparently takes less memory, so can be used with high pile-up.
  - look at the specialised tracking options, e.g. the GSF electron tracking.
  - Tracking seems to have improved drastically between software versions...

Standard geometry single electrons with p_T 35GeV (Tracker Detector Performance Group validation plots)



CMSSW 2.2.7[1]



CMSSW 3.1.2[2]

[1] http://cmsdoc.cern.ch/cms/performance/tracker/activities/reconstruction/tracking_performance/CMSSW_2_2_7/IDEAL_V12_noPU_ootb/RelValSingleElectronPt35/

[2] http://cmsdoc.cern.ch/cms/performance/tracker/activities/reconstruction/tracking_performance/CMSSW_3_1_2/MC_31X_V3_noPU_ootb/RelValSingleElectronPt35/

Future Plans - technical (cont.)

- Repeat the studies once the occupancy in the fast simulation has improved to match the full simulation
  - out of time pile up
  - delta rays
  - ...
- Add additional detector variation options
  - radiation damage
  - extra noise
  - ...
- Once the (normal) LHC is running tune to real data
  - probably just move to a tuned version of CMSSW

Future Plans - physics

- Continue the current studies
  - fix the problems with electrons.
  - try b-tagging at higher pile up.
  - look at pulls and resolutions.
- Expand the type of studies performed
  - ttbar.
  - physics study/studies (manpower?).
  - ...
- Expand the studies on detector variations
  - detector inefficiency.
  - vary the material in the tracking volume.
  - radiation damage.
  - location and size of layers, endcaps vs. long barrel.

Backup Slides

B-tagging

- Evaluated b-tagging performance with standard b-tagging validation using fastsim with digis

- Samples used for each run:
  - QCD light quark/gluon p_T = 50 – 120 GeV 2,000 events
  - c-cbar p_T = 50 – 120 GeV 2,000 events
  - b-bbar p_T = 50 – 120 GeV 2,000 events

- Relatively large samples needed to get good statistics on mistag rates

- Modified all packages to use old tracking instead of iterative tracking

- Algorithms:
  - Track counting
    - 3-D d0/σ of 2nd or 3rd most significant track
    - "High efficiency" or "high purity"
  - Jet Probability
  - Simple secondary vertex
  - Combined secondary vertex

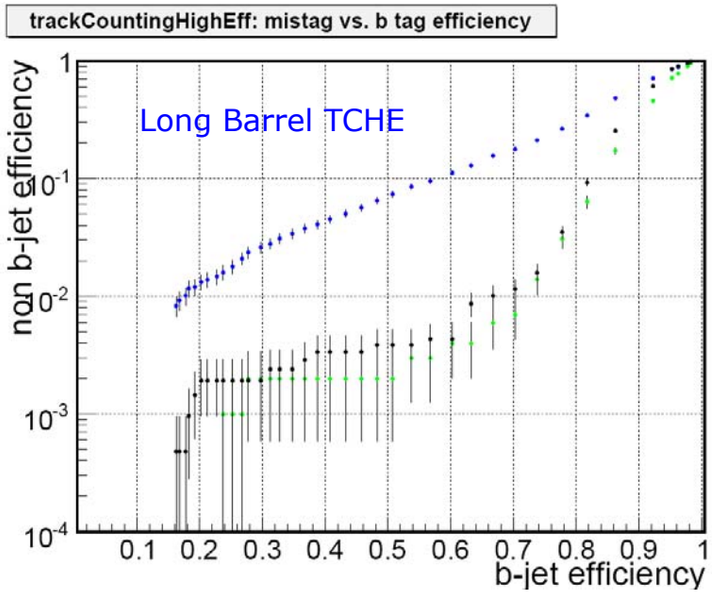
- Will show results for track counting algorithm – others later

Efficiency and Mistag Rate

- Tagging efficiency for *b*-jets $\varepsilon_b = \dfrac{\text{no. jets of flavor } b \text{ tagged as } b}{\text{no. jets of flavor } b}$

- Mistag rate for *udscg*-jets $\varepsilon_q = \dfrac{\text{no. jets of flavor } q \text{ tagged as } b}{\text{no. jets of flavor } q}$

Comparison With Std Geo TCHE PU0



- Compare with plots from validation web pages
- Approximately similar behavior
- Need to do proper comparison to validate